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A N A P P L I E D E A R T H S C I E N C E S C O M P A N Y

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PROJECT MEMORANDUM

To:	**Deloitte & Touche Inc.**	**Fax No.:**	**(416) 601-6151**
Attention:	**Shannon Glenn / Doug Sedgwick / Valerie Chort / Wes Treleaven**	**CC:**	
From:	**Jim Cassie, P.Eng. (Ext. 103)**	**Date:**	**January 7, 2002**
Subject:	**Summary Memo on Background and Rationale Reservoir Level Behind the FWS Dam, Faro Mine, YT**		
No. of Pages (including this page): 18 Pages		**Project No:**	**0257-010-03**

1.0 OBJECTIVE

During the Summer and Fall of 2001, BGC Engineering Inc. (BGC), in consultation with their client, Deloitte & Touche Inc. (Deloitte), have undertaken significant work relative to assessing some of the potential risks with the Fresh Water Supply (FWS) Dam. The highest perceived risk with this dam relates to the piping potential along the low-level pipe that runs along the base of this dam. The memo provided herein summarizes the technical work undertaken and the significant discussions held and decisions made in order to validate the following two-phase approach:

1. In order to reduce the potential risks with the dam, the current spillway of the FWS Dam is to be lowered by six meters (1096.1 m elevation to 1090 m) from February to April, 2002.
2. This temporary reservoir-lowering project is to be followed with a program that removes or rehabilitates the low-level pipe and again, significantly reduces the risks associated with this pipe. Concurrent or subsequent to the low-level pipe works, the FWS Dam is to breached or removed such that no significant reservoir and associated risks remain over the long term with this structure.

DIAND, as the stakeholder responsible for financing this work, requested that a business case be prepared, summarizing the technical assessment and feasibility studies performed, in order to provide rationale for the proposed capital expenditure.

2.0 STAKEHOLDERS INVOLVED

During this process, numerous stakeholders have been involved in the assessment of the technical work and in the decision making process. The following list summarizes the significant parties involved:

1. Deloitte: Wes Treleaven, Doug Sedgwick, Valerie Chort and Shannon Glenn.
2. DIAND and Geo-Engineering (M.S.T.) Ltd. – Dave Sherstone, P.Eng., Bud McAlpine, P.Eng. and Milos Stepanek, P.Eng.
3. BGC Engineering Inc.: Jim Cassie, P.Eng. and Gerry Ferris, P.Eng.
4. Anvil Range Mining Corp. – Dana Haggar.
5. Northwest Hydraulic Consultants – Eugene Yaremko, P.Eng.
6. Gartner Lee Ltd. – Eric Denholm and Steve Morison.

Memos were circulated to these parties as well as weekly conference calls starting on October 19th, 2001.

3.0 BACKGROUND ON THE FWS DAM

The FWS Dam was constructed in 1969 by the prime consultant H.A. Simons International Ltd., supported by the geotechnical consulting company of Ripley, Klohn and Leonoff Ltd. Immediately after construction, a small toe berm was placed due to concerns regarding seepage and related cracking at the toe. Following a stability assessment by Golder Associates in 1989, another toe berm lift, including toe drainage measures, was placed for enhancement of the downstream face stability.

The purpose of the dam was to retain a reservoir of fresh water that the mine processing operation would use through the winter period. Since that time, the water source requirements for the mill have changed and any required processing water would be obtained from the Faro pit. Hence, if the Faro Mine were reopened in the future, the processing operation would not need the reservoir currently retained behind the dam. Therefore, its role is redundant. When the dam retains water, there still exists potential risks with the dam and monitoring, inspection and maintenance of the dam requires significant expenditures.

It must be noted that the FWS Dam exists above the tailings containment area (that includes two major dams and a diversion channel) for the Faro Mine. Any catastrophic release of water from the upstream reservoir would likely remobilize the tailings deposit, damage or breach the two major downstream dams and release significant amounts of non-compliant water into the environment. It is also important to note that the current downstream diversion channel and the two emergency spillways are both sized to handle 1:500 year flood events.

As a condition of the Water Licence for the site, an annual geotechnical inspection and performance assessment of the major dams and structures on the Rose Creek and Down Valleys is performed. For numerous years, this annual document had been recommending that an inspection of the low-level pipe be performed so a condition assessment could be made.

In addition to the historic inspection and monitoring work, DIAND with their consultant, Geo-Engineering (M.S.T.) Ltd., have also been inspecting the facilities and documenting their concerns with the FWS Dam. Although BGC did not have access to all their reports, the following list is thought to summarize DIAND's main concerns with the FWS Dam:

1. Cracking is on-going on the crest of the dam that may extend to approximately 4 m below the crest level. Hence, there may be damage to this top portion of the dam.
2. Potential for piping along the low-level pipe.
3. The dam is not likely adequate to resist either extreme precipitation events (e.g. Probable Maximum Flood or PMF) or seismic events (e.g. Maximum Design Earthquake or MDE).

In May, 2001, BGC undertook a qualitative risk assessment (termed a Failure Modes and Effects Analysis or an FMEA) of the FWS Dam and the other dams and structures in the downstream Down Valley. The first draft of the summary report was submitted to Deloitte in June, 2001 and is referenced as BGC 2001a. Within that assessment, and noting the system boundaries and the assumptions made, the highest risk identified within all the structures reviewed was the low-level pipe. In addition, it was recommended that a complete Dam Safety Review (DSR), compliant with the guidelines of the Canadian Dam Association (CDA), be undertaken on the FWS Dam. An Executive Summary of that report is provided in Appendix A.

BGC also undertook an assessment of the physical stability of the FWS Dam that was submitted in draft in September 2001 and is summarized under BGC 2001b. This evaluation, based on limited information and the assumptions noted therein, attempted to determine the Factors of Safety for both sides of the dam, in comparison to the guidelines provided by the CDA. In summary, the current configuration of the dam meets most of the required Factor of Safety criteria for static conditions, dependent upon the soil properties assumed. Alternatively, the dam did not meet some of the Factor of Safety criteria for seismic loading, assuming a peak ground acceleration (PGA) value of 0.13g. It also reviewed the Factor of Safety for various breached cases on the FWS Dam. Again, a DSR was recommended, including an assessment of the low-level pipe, along with a more detailed assessment of the PGA values to be used for pseudo-static analyses. An Executive Summary of that report is provided in Appendix B.

4.0 CHRONOLOGY OF EVENTS AND TECHNICAL MEMOS

The following text outlines the fieldwork, decisions and memos undertaken since the initiating event of the pipe being inspected by the divers:

4.1 Diving Dynamics Inspection Results of September 18, 2001

BGC was informed in an evening phone call of the 1.5 m bend in the pipe, over a lateral distance of approximately 20 m, within the central portion of the FWS Dam. BGC recommended that the downstream valve be shut and preparations be made to lower the reservoir. BGC was also informed of the reduced wall thickness (measured by an ultrasonic tool) but that no signs of major structural distress were visually observed on the inside of the pipe. Diving Dynamics provided a formal report dated September 25, 2001.

4.2 Inspection Visit by BGC and D&T on October 4 and 5, 2001

Mr. Jim Cassie, P.Eng., of BGC was mobilized to site following observation of a "settlement hole" on the crest of the dam, supposedly adjacent to the area of the low-level pipe crossing. The "settlement hole" turned out to be a location of a previously dug test pit, that had settled slightly due to increased crest traffic. During this visit, no signs of settlement, cracking or turbid seepage (indicative of piping) were observed. In addition, the valve on the low-level was reopened to its previous location.

Deloitte prepared a summary memo on the status of the FWS Dam, dated October 6, 2001. This memo outlines the proposed options for a spillway required for lowering the pond level. In addition, a preliminary schedule for implementation of reservoir lowering project was provided.

BGC then provided a memo to Deloitte, dated October 8 (revised October 16), 2001, on the summary of observations made during the site visit and recommendations for future monitoring. The memo also reviewed a comparison of the survey data for the pipe that confirms that the majority of the low-level pipe is founded in bedrock, with appropriate seepage prevention collars. As such, it was deemed unlikely that the formation of a void from piping was responsible for the bend in the pipe. It is likely that the bend was created during installation of the pipe, but the as-built records for the pipe do not indicate such a bend in the pipe.

Following from previous work, two conclusive facts were known:

1. The pipe wall thickness has been significantly reduced from its original value of 9.5 mm (0.375 inch), down to values approaching 4.8 mm or 49% reduction. Therefore, some finite life remains for the pipe.
2. The bend in the pipe was measured but no concrete mechanism for its formation was determined. In addition, the entire inside of the pipe was not visually inspected due to the build-up on the inside of the pipe. As a result, there remains the potential risk that failure of the steel pipe and/or associated piping adjacent to it could still occur.

As a result of the potential risks, a defensive position was recommended and preparations were made to lower the reservoir, which including ordering 24 inch diameter pipe to act as a siphon.

4.3 Conference Call on October 19, 2001 Following Diving Inspection and Memos

A conference call was held between the various representatives of Deloitte, DIAND, BGC and Geo-Engineering with Wes Treleaven (Deloitte) serving as Chair of the call. The parties within the call agreed to three basic principals, based on the work carried out previously:

1. Given the potential risks with the dam, and its redundant role at site, it was decided that the dam has to be changed or removed from its present form, in order to reduce the potential short term and long term risks associated with it.
2. Further design work needs to be undertaken on the method of rehabilitation or removal, in consultation with DIAND.
3. Deloitte acknowledged that risk reduction should be the guiding principal and no risk should be shifted to other structures, following from the work to be carried out on the FWS Dam.

BGC proposed four work tasks to be undertaken over the short term, in order to assess the technical issues and the feasibility of undertaking the work on the dam. These were documented in a memo dated October 19, 2001 and consisted of the following four tasks:

1. Initial hydrotechnical assessment of the FWS Dam and the diversion channel in the Down Valley.
2. "Fatal flaw" analysis of the design and construction process for a proposed lowered spillway at the FWS Dam.
3. An assessment of the licencing and permitting issues relative to the construction of such a spillway.
4. Estimate of quantities and associated costing for the design and construction of such a project.

On November 5, 2001, BGC provided a summary memo on the schedule, issue review and costing assessment for the proposed FWS Dam reservoir-lowering project. In that memo, and the conference call that same day, several very important constraints and decisions were laid out, as summarized below:

1. Given the current capacity of the downstream Rose Creek Diversion Channel (RCDC), the new spillway required for lowering of the reservoir must be sized for compatibility with this downstream channel. Otherwise, risk reduction would be occurring at the dam while significant increases to potential risks would occur at the downstream channel. In addition, it would be practically impossible to completely drain the current reservoir in one winter in order to construct a complete depth breach of the dam. Thirdly, permitting of a complete breach project would be impossible within a short time period, given the consultation required with DFO on fisheries issues.

2. As a result of these constraints, a partial breach of the dam, compatible with the current downstream channel is to be undertaken this winter. This partial breach project, responsible for reduction in the short-term risks, is to be followed with either removal or rehabilitation of the low-level pipe, in order to reduce the risks with that structure. For that action to occur, further reservoir lowering from the first phase of lowering will be necessary. Following the rehabilitation of the low-level pipe, the entire FWS Dam is to be removed from service, when the issues of downstream size compatibility and permitting issues have been assessed.
3. Given that a partial breach is the only option for the short term reservoir lowering, three potential spillway locations were reviewed;
   i. At the current spillway location on bedrock.
   ii. In the middle of the dam, at the location of the previous creek bottom.
   iii. Directly above the location of the low level pipe.
4. For the second and the third options, some type of fill structure would have to be constructed on the downstream side of the dam to handle the discharge water. Compaction of fill materials (for the discharge structure) is almost impossible to do properly in the winter, and hence, practically, this is not really an option. In addition, when removal of the low-level pipe and/or a complete breach of the dam are implemented in the future, then the fill structure would have to be excavated and removed, resulting in wasted costs. As a result, the only practical choice for the short term reservoir lowering is to lower at the current spillway location that is sitting high on a bedrock knoll near the north abutment. In addition, a bedrock spillway will be able to handle higher flood velocities than a soil-based and rip-rapped spillway.
5. Following after the design of the reservoir-lowering project, additional data and information is to be collected on the condition of the low-level pipe and a decision made on its future. As noted earlier, additional lowering of the reservoir will be required to either remove or rehabilitate this pipe. As such, it may require another winter period of reservoir lowering to enact such work.
6. Studies and design work shall then be undertaken on the long-term closure configuration of the FWS Dam. Main constraints on the design will be the closure sizing criteria for water diversion structures, compatibility of outflow from the FWS dam with the downstream channel and the long-term management for the tailings within the Down Valley containment.

5.0 PATH FORWARD DECISION

Following from the memo and conference call of November 5, 2001, several additional work tasks were formulated as part of a “path forward” decision in order to confirm decisions described above and to provide necessary information to lower the spillway in a low risk, cost-effective manner. These included the following:

1. Assessment of the piping potential of the FWS dam.

2. Hydrotechnical assessment of the current hydrology within the Rose Creek basin and Down Valley, along with assessment of the current discharge capacity of the spillway on the FWS Dam.
3. Water balance assessment of the potential feasibility of lowering the reservoir within one winter period.
4. Dam break analysis of the potential consequences of a failure of the currently configured dam versus a dam with a lowered reservoir.
5. A comparison of the risk profiles between the current dam ("status quo" configuration) and the dam retaining a lowered reservoir level.

As noted previously, a guiding principal of the work proposed is to validate that a reduction of the risks associated with the dam is occurring. It is critical to understand that risk reduction does not imply risk elimination.

5.1 Piping Potential Memo by BGC

BGC provided a memo dated November 19, 2001 on the assessment of piping potential at the FWS Dam. Background on the issues of piping and filter design are provided as context for the reader. An explanation and assessment of the Weighted Creep Values for potential piping along the low-level pipe is performed. Based on the use of this basic index number, the dam would currently appear to be safe against piping. Further from this simple analysis, the memo notes that lowering of the reservoir will reduce the gradients in the dam, thereby reducing the potential for piping.

Mr. Milos Stepanek of Geo-Engineering provided his commentary on the BGC memo in his response memo dated November 23, 2001. He notes some issues with the points raised in the BGC but summarizes with the comment that "…lowering the reservoir level should decrease the piping hazard.".

Although not provided directly in the memo by BGC, the following simple calculations illustrates the level of risk reduction that may occur by lowering the pond level by 6 m:

1. Status quo dam – driving gradient along the pipe is equal to a head difference of 18 m over a pipe length of approximately 102 m. This is equivalent to an average gradient value of 0.18.
2. Lowered spillway – driving gradient along the pipe is equal to a head difference of 12 m over a pipe length of approximately 102 m. This is equivalent to an average gradient value of 0.12.

As can be seen, the hydraulic gradient along the low-level pipe, likely the main driver of potential piping, is reduced by approximately 33%, which is a significant reduction.

5.2 Hydrotechnical Assessment Report by NWHC

NWHC provided an assessment of the hydrology and the hydraulic capacity of the FWS Dam in the report, first provided in draft on November 22, 2001 and then finalized on December 11, 2001. Within that report, the following conclusions were reached:

- The earliest date of spring run-off was estimated to be April 14th. This date therefore constrains the end date for the completion of the reservoir lowering project.
- Flood sizes at the FWS Dam range from a 39 m^3/s for the 1:100 year event to 63 m^3/s for the 1:500 year event. The current spillway configuration can discharge 94 m^3/s to a level equivalent to the top of the dam core.
- PMF at the FWS Dam amounts to 550 m^3/s and hence, the dam spillway could not discharge this amount. During PMF, the dam would be overtopped.
- Flood sizes at the downstream end of the RCDC range from a 96 m^3/s for the 1:100 year event to 145 m^3/s for the 1:500 year event. The current RCDC is supposedly designed for a flow of 160 m^3/s.
- PMF at the downstream end of RCDC amounts to 1,680 m^3/s, approximately ten times its current design value.

Since the preparation of this report, NWHC has also provided further hydrotechnical input into the comparison of risk profiles, specifically for the hydrograph resulting from the construction of a new, lowered spillway.

5.3 Reservoir Lowering Assessment by BGC (with input by NWHC)

The reservoir at the 1096 m level of the concrete spillway contains approximately 5.7 million m^3 of water. For the temporary reservoir lowering to occur this winter, it is necessary to construct a new spillway to a lower elevation. As a result, it is necessary to draw down the current pond level to facilitate construction of the new spillway. Three possible methods exist to draw down the reservoir level, as outlined below:

1. Siphons.
2. Pumping.
3. Use of the low-level pipe.

At the current time, one pit pump at Faro has a capacity of approximately 0.4 m^3/s. At this discharge rate, approximately 10 days would be required to lower the pond level by 1 m. Given the concerns with regards to the low-level pipe and the cavitation noted when the valve was previously fully open in 1984, it was decided that the low-level pipe should only currently be used to discharge a water volume approximately equal to the reservoir inflows (approximately 0.2 m^3/s). Therefore, the only practical method of reservoir lowering was determined to be use of a 24 inch diameter siphon pipe.

If the siphons are unable to lower the pond level, and pumping is impractical due to power requirements, then the low-level pipe should be considered on a very conservative basis.

Use of a siphon pipe is limited to a head difference of approximately 6 m (exact head difference dependent upon the length of the siphon pipe and its associated frictional losses in the pipe). As a result, given the practical constraints of lowering the pond level during this one winter season, it was determined that the 6 m drop would be achievable, and hence, served as the target draw down value for the reservoir. A complete memo on reservoir lowering predictions and issues was provided to Deloitte on November 13, 2001.

During lowering of the upstream side pond, it is possible that a "rapid draw down" failure can be initiated. As a result, BGC has provided monitoring recommendations to Deloitte in order to assess the internal pore pressures in the FWS Dam during draw down. This data is then reviewed relative to the Factor of Safety on the upstream face of the dam.

5.4 Dam Break Analyses by NWHC (with input by BGC)

In order to assess the potential consequences of failure of the FWS Dam, NWHC undertook a dam break analyses using the software DAMBREAK and HEC-RAS. Within these analyses, the "sunny day" piping event was postulated to occur along the low-level pipe for two different cases; i) the status quo dam with the reservoir level at 1096 m elevation and ii) the lowered configuration with the reservoir at elevation 1090 m, approximately 6 m lower than the first case. It should be noted that the reservoir volume at 1096 amounts to approximately 5.7 million m^3 of water. With the reservoir at 1090 m, the water volume is reduced by approximately 40%.

The model formulates a breach occurring at the dam and generates an outflow hydrograph from the dam. The flood is then routed along the topography of the downstream valley and an assessment of the outflow flooding can then be made. Table 1 provides a summary of the two cases, as verbally provided by NWHC on December 19, 2001:

Table 1: Comparison of Dam Break Cases

Parameter	**Status Quo Dam with Pond at 1096 m**	**Lowered Case with Pond at 1090 m**
Peak outflow quantity from breach (m^3/s) at the FWS Dam (relation to PMF size)	3,200 (approximately 6 times the PMF size for this dam)	1,800 (approximately 3 times the PMF size for this dam)
Depth of flood water above tailings deposit (m)	2 to 3	1.5
Discharge water velocity (m/s)	>3	2.5
Fate of downstream Intermediate and Cross Valley Dams	Washed away	Washed away

Since a water velocity of approximately 0.4 m/s is required to erode fine sand particles, it can be seen that the flood wave would erode and displace the tailings in the Down Valley. Given the abilities of the model, coupled with the likely breach of the two downstream dams, it is not possible to estimate the amount of tailings erosion and/or the far downstream distribution of these eroded tailings.

Based on the results of the dam break analyses provided in Table 1, there would appear to be little significant difference in the resulting failure consequence from the two cases, noting the sensitivity of the model and the assumptions made therein. The flood wave in both cases is significantly larger than the PMF sizing and as a result, extensive downstream damage would occur in both cases. If the Intermediate Dam pond was low, and some storage capacity existed within that basin, there is the possibility that some attenuation of the smaller flood wave could occur.

5.5 Final Design Configuration

BGC provided a memo dated December 13, 2001 that outlines the expected new spillway sizing, the quantities and costs surrounding this sizing and a preliminary list of potential design, construction and performance issues relative to the new spillway. The following list summarizes the relevant points from that memo:

- The new spillway will be 6 m deep (from the current concrete sill elevation of 1096.1 m) and it will be 7 m wide.
- The new spillway will be blasted into the phyllite bedrock at its current location.
- This new spillway, when coupled with the discharge capacity of the current spillway, and the flood routing ability of the lowered spillway, will now be able to handle a PMF inflow without the occurrence of overtopping.
- Approximately 5,500 to 8,000 m^3 of excavation are required for this channel. Based on these quantities, the direct cost of construction is estimated to range from $240,000 to $315,000, not including any allowances for contingency. These costs may change if geotechnical and/or topographic conditions dictate changes to the spillway geometry.
- The new spillway will be designed for the 1:500 year flood event (rip rap sizing, etc.).
- Within the design intent for this temporary spillway, it is noted that the design life for this structure will be five years. It is also acknowledged within the design intent that the low level pipe is to be removed or rehabilitated within two years of the reservoir-lowering project.

At the meeting on Dec. 14th, the indirect costs of engineering and construction supervision were estimated to cost approximately $195,000 (which may change as the final work scope develops). As a result, the total direct construction and indirect costs would amount to approximately $500,000, not including any allowance for contingency items.

5.6 Comparison of Risk Profiles Memo by BGC

A memo comparing the risk profiles between the status quo dam and the 6 m lowered version was submitted in draft on December 10, 2001. Within that memo, Table 1 provided several categories of risk issues for comparison. It should be noted that "risk" implies two separate components; the likelihood of occurrence and the potential consequences. Generally, the concept of risk "costs" provides for the cost of the consequence, multiplied by the probability of occurrence.

Although the memo provided by BGC provides some context and discussion of the results, the attached Table 1 presents the main results of the comparison. Within that table, 22 potential mechanisms are assessed. Of those proposed mechanisms, in twelve cases, risk reduction or significant risk reduction is expected to occur following the lowering. Based on these results, and BGC's understanding of the potential risks at site, the following top three risks are addressed as follows:

1. Potential for piping along the low-level pipe: Based on the assessment, lowering of the reservoir will reduce the average hydraulic gradient, likely the main mechanism responsible, by 33% and hence, reduce the potential for piping. This is a risk reduction in the likelihood of a piping event occurring.
2. Piping within the frost-affected zone: Based on the new, lowered spillway configuration, the pond will never again be retained within this zone of the dam, unless an event approaching the PMF size is retained. This is a significant risk reduction in the likelihood of occurrence.
3. Ability to handle extreme precipitation events: Based on the new lowered spillway, the additive abilities of the two spillways and the extra storage capacity behind the dam, it is now possible that the FWS Dam could handle the inflow of PMF event without overtopping.

Given that a capital expenditure of approximately $500,000 is anticipated for this work, the three risk reductions reviewed above appear adequate to support the case for undertaking the work.

It should be noted that the construction of the lowered spillway during this winter is not risk free. Blasting of the bedrock will be required directly adjacent to the operational dam. The low-level pipe may have small cracks that may be exacerbated by the construction activities. Specialist blasting expertise will be brought to bear on the design team in order to prevent damage from occurring to the dam and the low-level pipe, based on previous experience. A test-blast, coupled with blast monitoring of the structure, will be diligently carried out to ensure compliance of blast size with specified levels of peak particle velocities.

6.0 SUMMARY AND CLOSURE

As outlined in the previous sections, numerous risks exist with the current configuration of the FWS Dam. As such, it is recommended that a temporary lowering of the retained reservoir level be undertaken this winter to reduce these risks, generally focused on reducing the likelihood of occurrence of piping along the low-level pipe. This lowering is only the first phase of the two phase (the second is pipe removal/rehabilitation followed by complete dam breaching) project aimed at the removal of the FWS Dam from service along Rose Creek. If the water is not lowered this winter, another opportunity to reduce the risks will not practically occur until the winter of 2002/03.

Respectfully submitted,
BGC ENGINEERING INC.
per:

James W. Cassie, M.Sc., P.Eng.
Specialist Geotechnical Engineer

JWC/sf

Attachments: Appendices A and B
Revised Table 1 from Risk Comparison Memo

REFERENCES

BGC Engineering Inc. 2001a. Qualitative Risk Assessment of the Down Valley Tailings Area. Report submitted to Deloitte and Touche Inc., Project No 0257-004, Draft submitted in June, 2001, finalized November, 2001, 27 pages.

BGC Engineering Inc. 2001b. Physical Stability Assessment of the Fresh Water Supply Dam. Report submitted to Deloitte and Touche Inc., Project No 0257-006-03, Draft submitted in September, 2001, finalized November, 2001, 25 pages plus figures and appendix.

APPENDIX A

EXECUTIVE SUMMARY

The following Executive Summary is provided as a synopsis of the attached report for the convenience of the reader. It should only be read in conjunction with the attached report, which should be read in its entirety. BGC Engineering Inc. cannot be held liable for any errors or omissions resulting from reading only this Executive Summary.

Deloitte and Touche Inc., in their role as Receiver for Anvil Range Mining Corporation, is managing the currently shut-down Faro Mine. As part of their overall site planning process, and in response to potential dam stability concerns raised by Indian and Northern Affairs Canada, BGC Engineering Inc. (BGC) undertook a qualitative risk assessment study for the Fresh Water Supply Dam and the other mine waste containment and water retaining and diverting structures within the Down Valley tailings area. A Failure Mode and Effects Analysis (FMEA) type of risk assessment was undertaken for the existing structures within the Down Valley.

The primary objective of this study is to identify potential failure modes, firstly with the Fresh Water Supply Dam and secondly, with the other various dams, diversion canals and associated structures (within the Down Valley tailings area only) and to estimate the probability of these failures occurring, in order to assess the risks. The secondary objective of this study is to communicate both the risk assessment process and the potential risks to interested stakeholders. The risk assessment exercise is intended to provide a level of understanding and enhanced awareness of the potential hazards, both with individual structures, such as the Fresh Water Supply Dam, and with the overall containment system, associated with the Down Valley tailings area.

In an FMEA, the effects or consequences of individual component failure modes are systematically identified. The FMEA is intended to be a formalized method of project review or engineering reliability technique that will identify risks and allow the characterization and qualitative ranking of risks. The FMEA process does not in itself reduce risks. The four following personnel attended the FMEA meeting in Calgary on May 8 to 10, 2001:

1. Dr. Iain Bruce, P.Eng. (BGC) – Facilitator and Principal Geotechnical Engineer.
2. Mr. Eric Denholm (Gartner Lee Limited) – Formerly Senior Environmental Engineer at Faro Mine and now and Environmental Consultant to D&T on Faro issues.
3. Mr. Jim Cassie, P.Eng. (BGC) – Geotechnical Consultant to D&T on Faro issues.
4. Mr. Glen Gilchrist, P. Eng., (Golder Associates Ltd.) – Formerly, Geotechnical Consultant to both Curragh Resources and Anvil Range Mining Corp. on Faro tailings issues.

The team members worked together to review potential failure modes, assign probabilities of failure occurrence and assess the consequences of failures. Lists of elemental failure modes for dams, waste dumps and diversion channels were developed, based on external statistical work and from internal experience within the review team.
The systems bounds, including the major elements (such as a dam) and links (such as a spillway), within the Down Valley tailings system were outlined. A summary of the physical conditions, major components and structures and water handling processes within the Down Valley was provided.

For the FMEA to be carried out, it is necessary to define appropriate categories for the likelihood of occurrence, the consequences of failure and the confidence limits for each of the two preceding categories. The category selection is necessary in order to calibrate the subjective rankings of the members of the review team. Following from the category definitions, four categories of risk were proposed for this project: High, Moderately High, Moderate and Low. The selected categories of risk are based on the combination of the likelihood of failure occurring, along with the consequences of failure. For each of the four categories proposed, recommendations for the timing of additional work to define and implement remedial action plans are provided.

Within the FMEA study undertaken, for the currently configured structures within the Down Valley tailings area, 127 risk rankings were obtained for various failure modes. Of these 127 risks, 1 was ranked as a High Risk and 34 were ranked as Moderately High for the current configuration of the system. The one High risk occurred with the Fresh Water Supply Dam, which is related to the piping potential of the low level pipe. High risks should have a defined remedial action plan within the next six months and Moderately-High risks should have a remedial action plan within the next six to twelve months.

Six cases, beyond the 127 cases noted above, were also considered with the potential removal of the Fresh Water Supply Dam from the system. In all six cases, the risk ranking appeared to increase with the removal of the Fresh Water Supply Dam. Given the demonstrated importance of the Fresh Water Supply Dam, and acknowledging the potential risks with this structure, it is recommended that the first priority for any additional work in the Down Valley be a hydrotechnical assessment and a Dam Safety Review, in compliance with Section 2.0 of the Canadian Dam Safety Guidelines. Inclusive within this overall safety review should be a piping assessment of the low level pipe. In addition, the physical stability assessment work pertaining to the dam, currently under preparation under separate cover would also form a portion of the Dam Safety Review.

Following from the Fresh Water Supply Dam safety review, next in importance are the potential risks related to seepage and piping potential and the liquefaction of the three major dams and their foundations. Last in priority are an assessment of the foundation conditions beneath the Intermediate Dam, an evaluation of the landsliding potential over top of the Cross Valley pond and reviews of both operational and maintenance protocols and emergency response plans.

APPENDIX B

EXECUTIVE SUMMARY

The following Executive Summary is provided as a synopsis of the attached report for the convenience of the reader. It should only be read in conjunction with the attached report, which should be read in its entirety. BGC Engineering Inc. cannot be held liable for any errors or omissions resulting from reading only the Executive Summary.

Deloitte and Touche Inc. retained BGC Engineering Inc. (BGC) to assess the current condition of the Fresh Water Supply Dam, in terms of its physical stability, relative to storing water behind this currently redundant dam. Further to this objective, potential breaching options and lowering of the retained reservoir level was also evaluated. It should be noted that modifications considered for the Fresh Water Supply Dam, a single structure, must be considered in the overall context of the entire tailings containment system.

This report provides a geotechnical assessment of the physical stability, based on stability analyses for the currently configured dam. The current assessment provided herein does not address any of the hydrotechnical issues related to this dam, which are likely to be as important as the geotechnical issues. BGC Engineering Inc. previously undertook a qualitative risk assessment (a Failure Modes and Effects Analysis) of the engineering issues, both for this dam and the other structures within the Down Valley. Within that study, the potential piping risk with the low level pipe that goes through the Fresh Water Supply Dam was identified as ‘High Risk’.

A review of existing information, comprised of as-built drawings, various reports on the dam construction and monitoring, along with previous stability analyses were combined with recent survey and instrumentation data to form a synthesis of the current condition of the dam. In addition, a review of the current dam safety guidelines was included to provide context for the stability analyses. As part of that assessment, an evaluation of the potential seismic loading parameters was undertaken, based on the seismic hazard assessment undertaken for the Faro Mine closure plan, previously submitted in 1996.

Four different cases were assumed with regards to frictional values for the various materials in the dam. Based on the assumptions noted herein, the following conclusions are reached with regards to the current configuration of the dam:

- The dam does not meet seismic requirements if the Case 1 soil properties are assumed.
- Using the Case 2 soil properties, the downstream and the upstream faces of the dam are considered stable under static conditions, according to the Factor of Safety requirements. The downstream face of the dam is considered stable under the specified seismic loading conditions, while the upstream face is not considered stable.
- For the Case 3 soil properties, the dam is considered stable for both faces under static conditions. Under the specified seismic loading, the downstream face is considered stable and the upstream face is nominally equal to the required Factor of Safety.

- For the Case 4 soil properties, the dam is considered stable in all cases.
- The inclusion of a weakened, 3 m deep soil layer beneath the crest of the dam has a minimal effect on the static stability of the upstream or downstream face of the dam.
- If the current phreatic surface increases by approximately 0.5 m within the dam embankment, the static Factor of Safety decreases by a minor amount.

Three partially breached cases (2, 4 and 8 m decreases in reservoir elevation) and a complete breach case were also analyzed in terms of their physical stability. The results indicate that the stability of the downstream face of the dam increases as the water level in the reservoir is lowered. For all cases, the Factor of Safety exceeds the 1.5 required for the stability of the downstream face of a dam under static conditions. Additionally, the Factor of Safety exceeds the required 1.1 for the stability of the downstream face under seismic loading conditions. For the upstream face, the Factor of Safety exceeds the required 1.5 for the stability of the upstream face of under static conditions, noting the “partial pond” phenomena. Factors of Safety less than 1.1 were calculated for the upstream face under seismic loading conditions for the current full supply level, 2 m drop and 4 m drop cases using Case 1 and 2 material strength parameters. Using Case 3 soil strength parameters, Factors of Safety just less than 1.1 were calculated for the current full supply level and 2 m drop scenarios. For breaches of 8 m and greater, the Factor of Safety increases significantly.

A Dam Safety Review is recommended for the final assessment of the safety of the FWS Dam.